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# Predicting
# Summer Production Losses
# for Swine

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## Contents

# Predicting Summer Production Losses for Swine

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## INTRODUCTION

In many areas of the United States, summer temperatures have a detrimental effect on swine production, especially when the temperature and humidity are high.[2] An estimate of expected losses in summer production at a given location could help in deciding whether a modified or controlled environment for swine would be worthwhile. Earlier work[3] has shown that to determine such a measure requires (a) a

functional relationship between production and climate, and (b) the probability of occurrence for given weather. In this report to satisfy the requirements for (a), we used a recently developed relationship between rates of swine growth and air temperature and humidity and for (b), climatological records for 16 U.S. locations to establish empirical probabilities of the weather.

## PRODUCTION RELATIONSHIP

The relationship between production and temperature and humidity is taken from a study by Morrison and others (see reference listed in footnote 2).

These authors used experimental data for production response to temperature.[4] Data for 150-pound pigs were used (fig. 1) with the production variable changed to
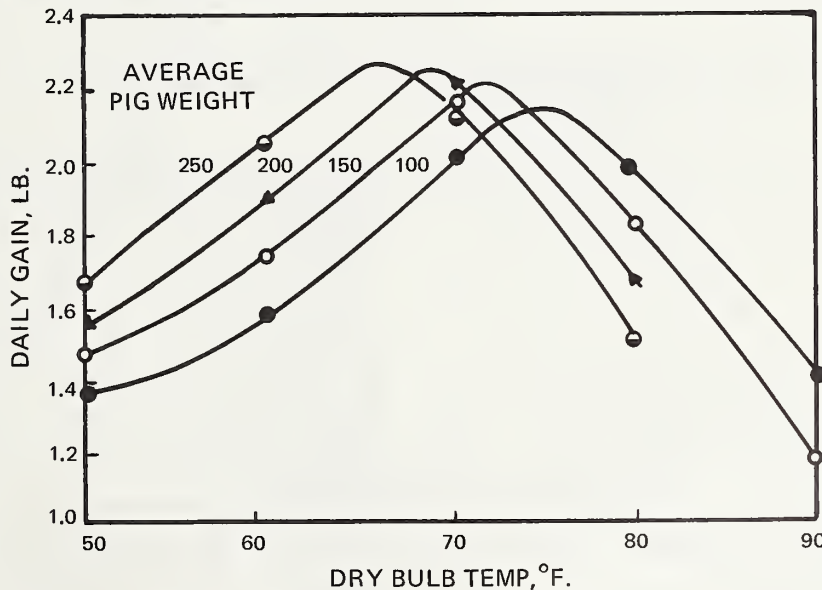


Figure 1.—Weight gains in swine at a constant relative humidity of 50 percent as a function of air temperature and live weight based on data from Heitman, Kelly, and Bond (reference listed in footnote 4).

[1] Mr. Hahn is stationed at Columbia, Mo., and Mr. Bond at Davis, Calif.

[2] Morrison, S. R., Bond, T. E., and Heitman, H. Jr. Effect of humidity on swine at high temperature. Amer. Soc. Agr. Engin. Trans. 11: 526-528. 1968.

[3] Hahn, G. L., and McQuigg, J. D. Expected production losses for lactating Holstein dairy cows as a basis for rational planning of shelters. 1967. Paper No. 67-107 presented at annual meeting of Amer. Soc. Agr. Engin., St. Joseph, Mich., March 31, 1967.

gain as a fraction of maximum gain. Thus, these data could be used for pigs fattened under conditions that could result in different gains at optimum temperature. In this study, 72° F. at 50 percent humidity was

[4] Heitman, H., Jr., Kelly, C. F., Bond, T. E. Ambient air temperature and weight gain in swine. Jour. Anim. Sci. 17: 62-67. 1958.
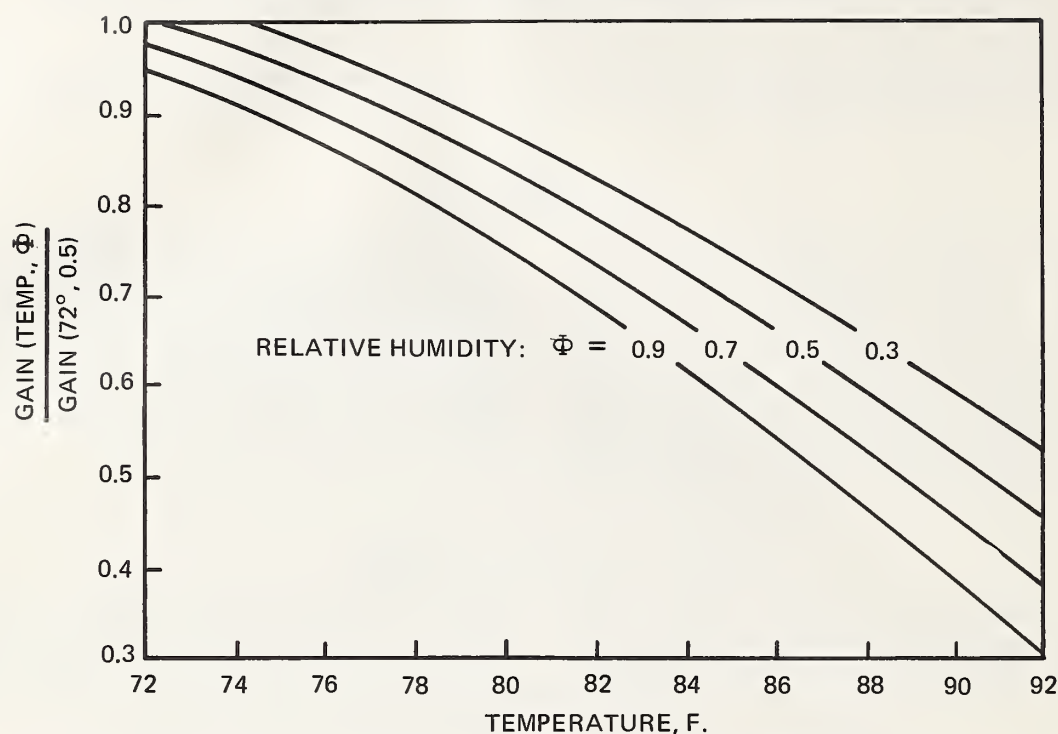
Figure 2.–Ratio of weight gain for 150-pound pigs at a given relative humidity and temperature to that at 72° F. and 50 percent humidity (Φ = 0.5). (Curve labeled Φ = 0.5 from figure 1.)
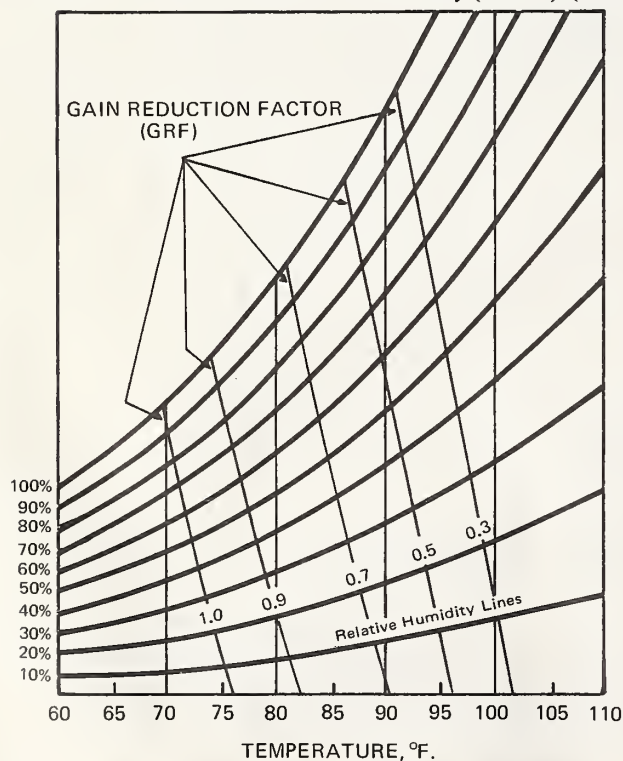


Figure 3.–Gain Reduction Factors graphically represented as a function of air temperature and humidity on a psychrometric chart.

assumed to be optimum for 150-pound pigs under any conditions. The effect of humidity on weight gain was determined analytically, and the results verified by experiments.

The results of this study are given in figure 2, wherein the ordinate represents the ratio of the gain of 150-pound pigs at a given condition to that at 72° F. and 50 percent relative humidity, and is denoted Gain Reduction Factor (GRF). The relationship in figure 2 can also be plotted on a psychrometric chart (fig. 3). The lines of constant GRF are equivalent to lines of a constant temperature-humidity index (THI). This index has an advantage over other available indices since the values are in terms of an animal production variable. A disadvantage is that the variable is not explicitly expressed as a function of psychrometric variables such as the well-known $THI = 0.55t_{db} + 0.2t_{dp} + 17.5$, where $db$ refers to the dry-bulb temperature and $dp$ the dewpoint (THI refers to temperature-humidity index). However, each of the three relationships used to derive the curves in figure 2 can be approximated by second-degree equations. The relationships are the rate of gain of 150-pound pigs at 50 percent relative humidity, the fraction of total heat lost by evaporation from 150-pound pigs, and the enthalpy of saturated air,

each as a function of temperature above 72°. The resulting equation would be cumbersome for ordinary operations (a sixth-degree equation), but not with high-speed digital computers.

## WEATHER EVENT PROBABILITIES

While probability estimates based on frequency ratios provide only an approximation of the mathematical probabilities, they can provide meaningful results when large samples of data are used.[5] Nonparametric, or estimated, probabilities then provide a basis for prediction, with the understanding that two assumptions have been made.

1. The probabilities are based on random samples.
2. The population is stationary in time.

7040 computer.[6] This program (1) determined and printed daily average, maximum, and minimum GRF values for each day, (2) determined and printed mean, standard deviation, skewness, and kurtosis values for each year's data, (3) arrayed daily average GRF values, and finally (4) computed and printed the empirical probability of each GRF class interval occurring in a summer season and the cumulative probability.

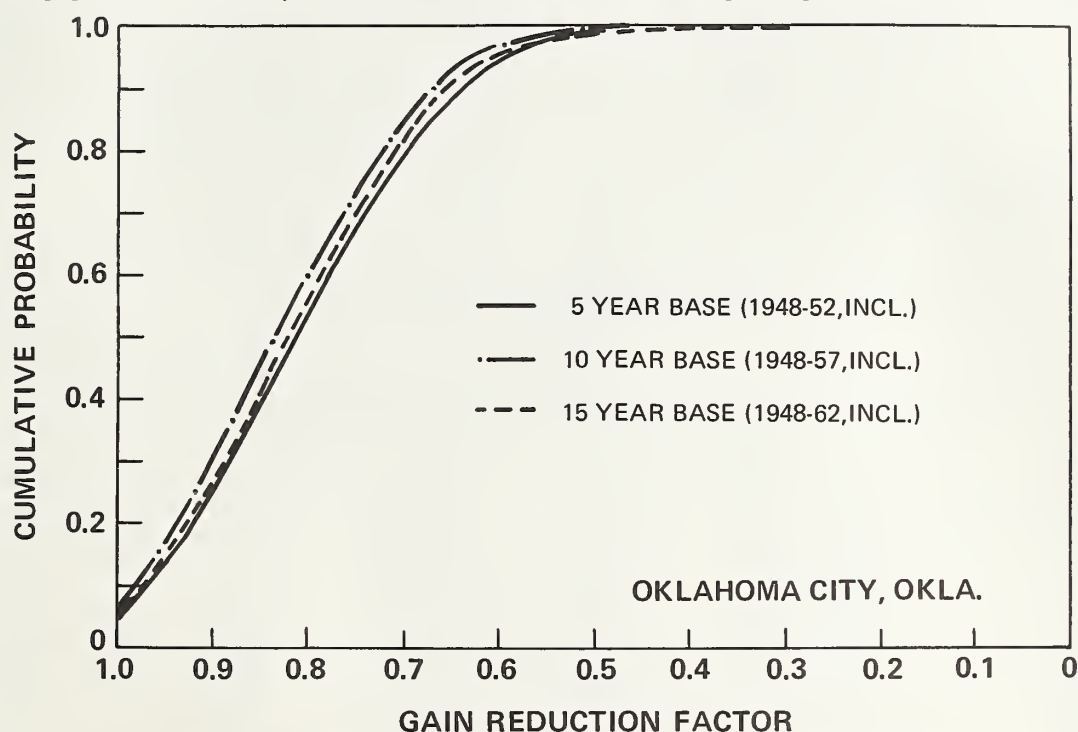The computer program was used to determine



Figure 4.—An example of the effect of different record lengths on the cumulative probability curve.

Production losses have been related to temperature and humidity, two variables which are routinely measured at all first-order weather stations. Hence, reasonably long-term records are readily available for computing probabilities.

The hourly climatological records were placed on magnetic tape, and a program was compiled on an IBM

estimated probabilities based on 5- and 10-year records, in addition to the maximum record available for the individual stations. When the differences among the cumulative frequency curves (distribution functions) were compared, generally only slight variations were

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[5] Panofsky, H. A., and Brier, G. W. Some applications of statistics to meteorology. Pa. State Univ., University Park. 1963.

[6] Trade names are used in this publication solely for the purpose of providing specific information. Mention of a trade name does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture or an endorsement by the Department over other products not mentioned.

found. This is illustrated in figure 4 for Oklahoma City, Okla., using 5-year records (610 daily mean GRF values), 10-year records (1,220 values), and 15-year records (1,830 values).

The minimum period that can safely be used in developing the distribution functions is probably 5 years, as an occasional station had differences in the probability of occurrence of a GRF value of 5 to 10 percent when comparing the 5-year and the 10- or 15-year curves. Had the distributions been normal, even fewer years would have been adequate. Normality, as tested for the Oklahoma City station for each of the 15 seasons, gave a range of skewness from -0.9 to -1.4 and of kurtosis from 2.9 to 5.3. A normal distribution would have provided a skewness value of 0 and a kurtosis value of 3.0 from the equations used in the computer program. The actual distributions for the yearly data, therefore, tended to be skewed negatively (mode is higher than mean) and to be somewhat peaked (Leptokurtic). Ranges of normality tests for the remaining stations (table 1) show much the same tendencies, although some are more extreme.

The 4-month period of June 1 to September 30 was used in this study for all stations to permit direct comparison of the various locations. For most stations relatively few days would be outside this interval during which there would be production loss due to high temperature or high humidity or both, although a few stations—Phoenix, for example—would have such days. During this summer interval, there are days when the average temperature declines below 72° F. Figure 1 predicts that below 72° production will decline; however, housing and huddling would prevent the environmental temperature (including the effects of nearby animals, radiation from the walls, and so forth) from declining as much as air temperature. Findings of one study[7] showed that pigs raised in temperatures ranging from 50° to 75° performed about equally, so perhaps the curves of figure 1 should have less of a peak. For these reasons, the GRF was assigned a value of 1.0 for days with average temperature below 72°. In other words, production loss due to low temperature was not included.

TABLE 1.–Gain Reduction Factor (GRF) data for selected stations for the summer period June 1 to September 30

| Station | Period of record | Range of normality tests | | Probability for GRF = 0.80 or more | Mean GRF for summer period |
| | | Skewness | Kurtosis | | |
| --- | --- | --- | --- | --- | --- |
| Atlanta, Ga. . . . . . . . . | 1/49 - 12/58 | -0.9 to -1.5 | 2.8 to  5.6 | 0.69 | 0.84 |
| Barbers Point, Hawaii  . . . | 1/50 - 12/64 | -.3 to  -.6 | 2.0 to  5.1 | .96 | .85 |
| Beeville, Tex.. . . . . . . . | 1/53 -  9/63 | -.5 to -1.1 | 2.5 to  5.0 | .13 | .70 |
| Boise, Idaho . . . . . . . . | 1/49 - 12/58 | -1.9 to -2.9 | 6.1 to 17.2 | .92 | .92 |
| Cheyenne, Wyo. . . . . . . | 1/49 - 12/58 | -2.7 to -5.0 | 16.4 to 47.1 | .99 | .97 |
| Columbia, Mo.. . . . . . . | 1/45 - 12/64 | -2.8 to -6.0 | 15.9 to 59.0 | .94 | .93 |
| Dallas, Tex. . . . . . . . . | 3/45 - 12/64 | -.6 to -1.4 | 2.7 to  7.3 | .23 | .68 |
| Dayton, Ohio . . . . . . . | 1/49 - 12/58 | -1.4 to -2.8 | 4.3 to 16.0 | .87 | .90 |
| Harrisburg, Pa.. . . . . . . | 1/49 - 12/58 | -1.6 to -2.2 | 5.0 to  8.4 | .90 | .92 |
| Lone Rock, Wis.. . . . . . . | 1/49 - 12/54 | -1.7 to -2.4 | 5.6 to  8.5 | .93 | .93 |
| Massena, N.Y. . . . . . . . | 1/49 - 12/58 | -1.9 to -3.0 | 5.8 to 12.7 | .97 | .95 |
| Memphis, Tenn. . . . . . . | 3/45 - 12/64 | -.7 to -1.6 | 2.5 to  3.6 | .50 | .79 |
| Oklahoma City, Okla.  . . . | 1/45 -  5/64 | -.9 to -1.4 | 2.9 to  5.3 | .56 | .81 |
| Phoenix, Ariz. . . . . . . . | 1/49 - 12/58 | -1.9 to -5.6 | 10.0 to 62.6 | .09 | .52 |
| Sacramento, Calif.  . . . . . | 1/49 - 12/58 | -1.7 to -3.3 | 5.3 to 18.7 | .87 | .89 |
| Sioux Falls, S.Dak. . . . . . | 1/49 - 12/64 | -1.7 to -2.5 | 5.2 to  9.8 | .89 | .92 |

## RESULTS AND DISCUSSION

The results of the computations have been plotted in figure 5. Thus, the probability that GRF = 0.80 or better at Atlanta is 0.69; or conversely, 31 percent of the time a GRF less than 0.80 can be expected. The shape and position of the curves generally reflect the climate of the stations. For example, the even, warm climate of Barbers Point, Hawaii, results in a GRF better than 0.90 only 8 percent of the time, but better than 0.80, 96 percent of the time.

[7] Mangold, D. W., Hazen, T. E., and Hays, V. W. Effect of air temperature on performance of growing-finishing swine. Amer. Soc. Agr. Engin. Trans. 10: 370-375. 1967.
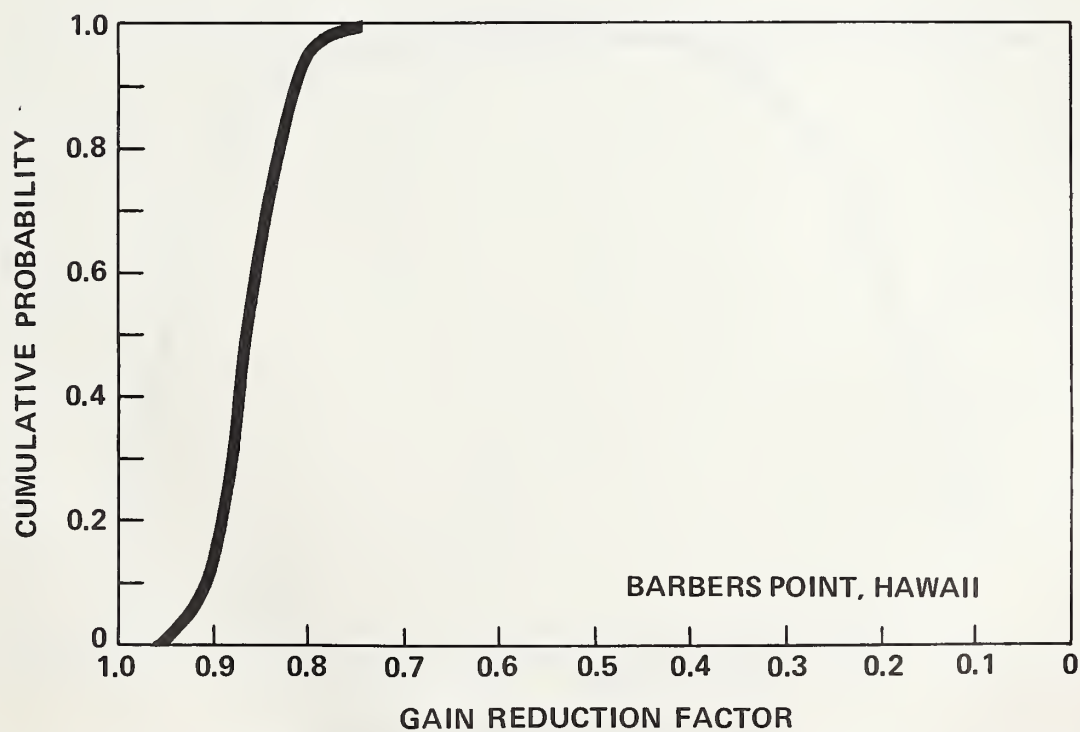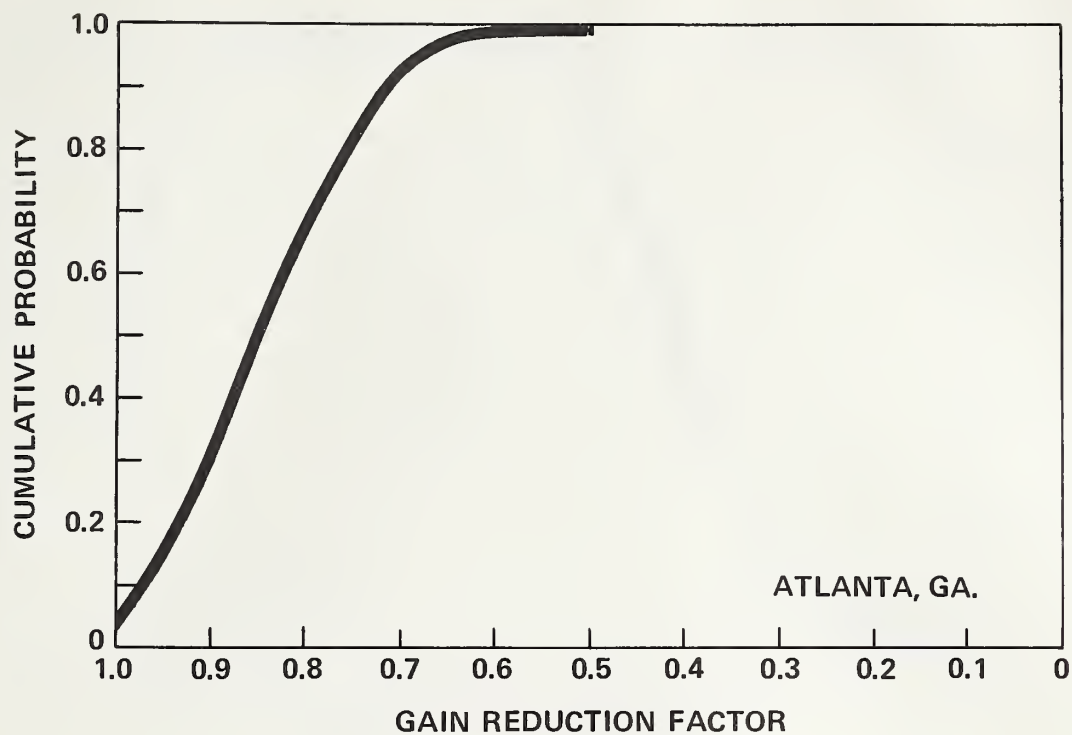
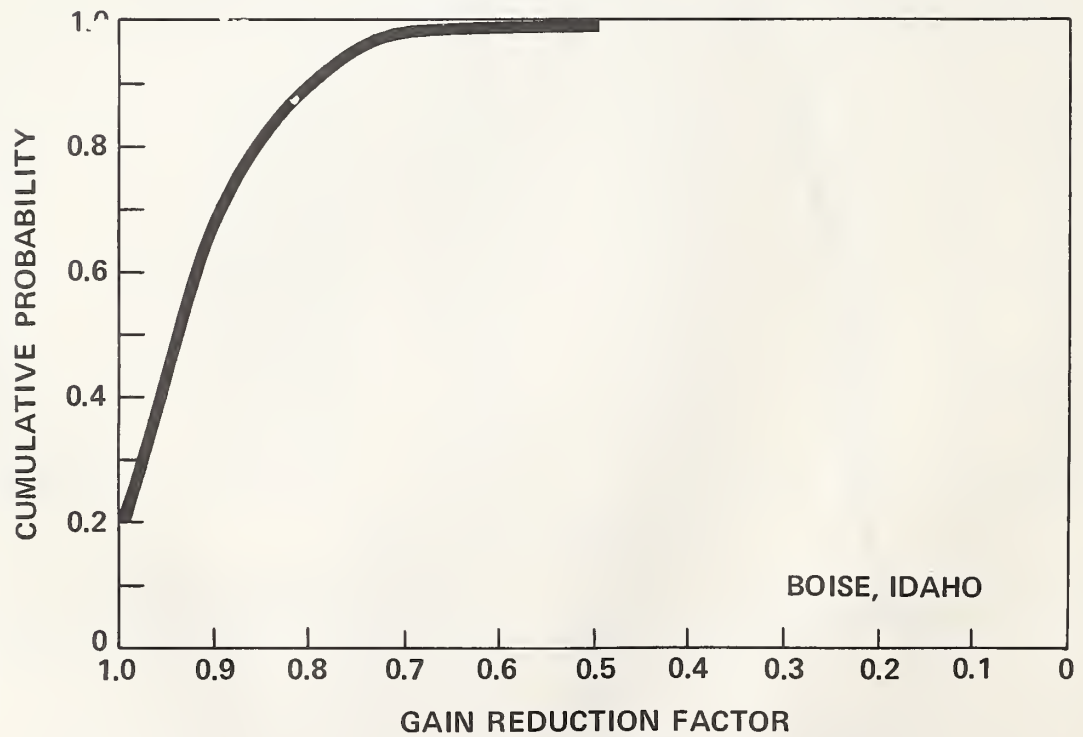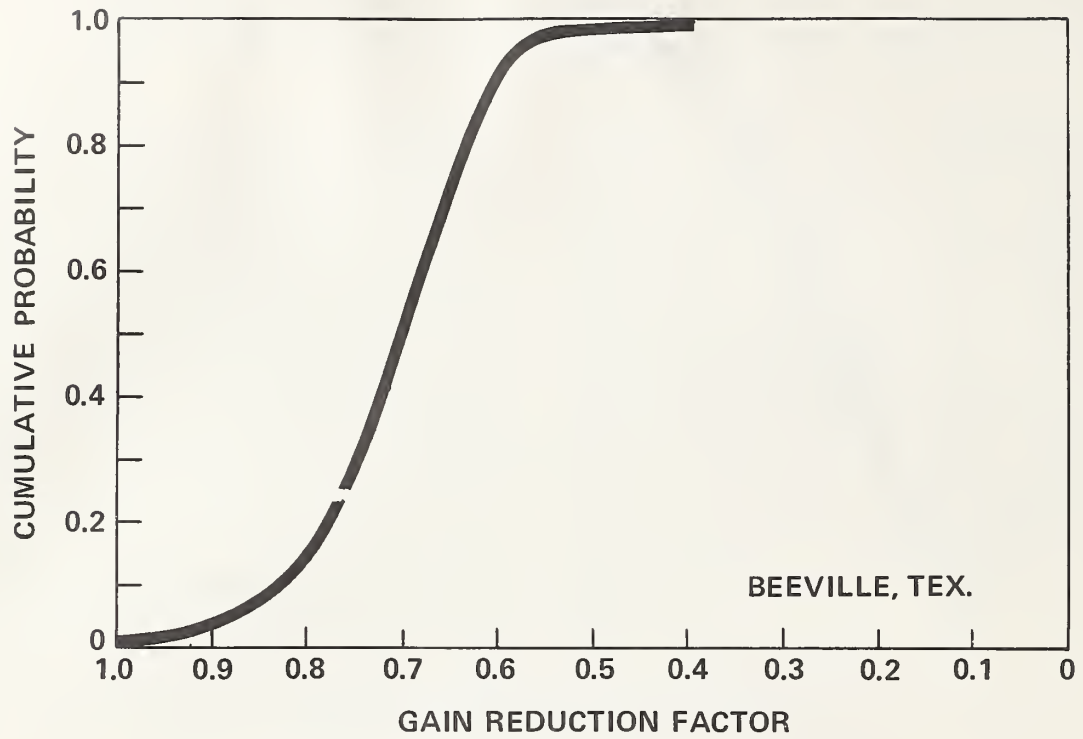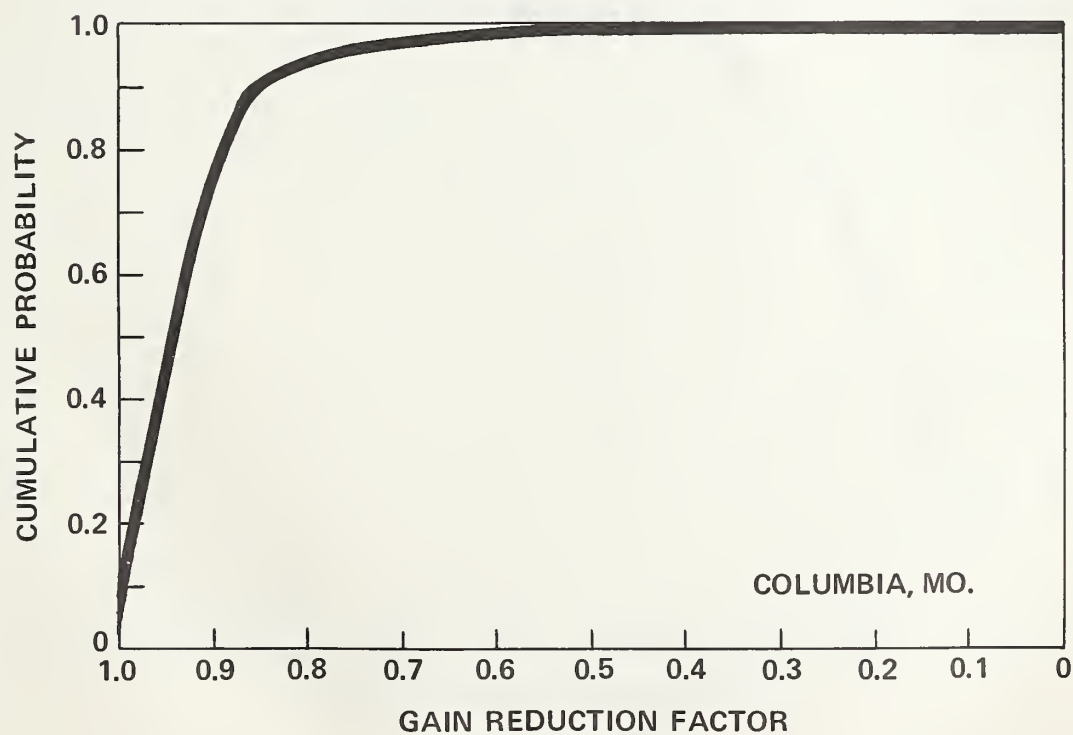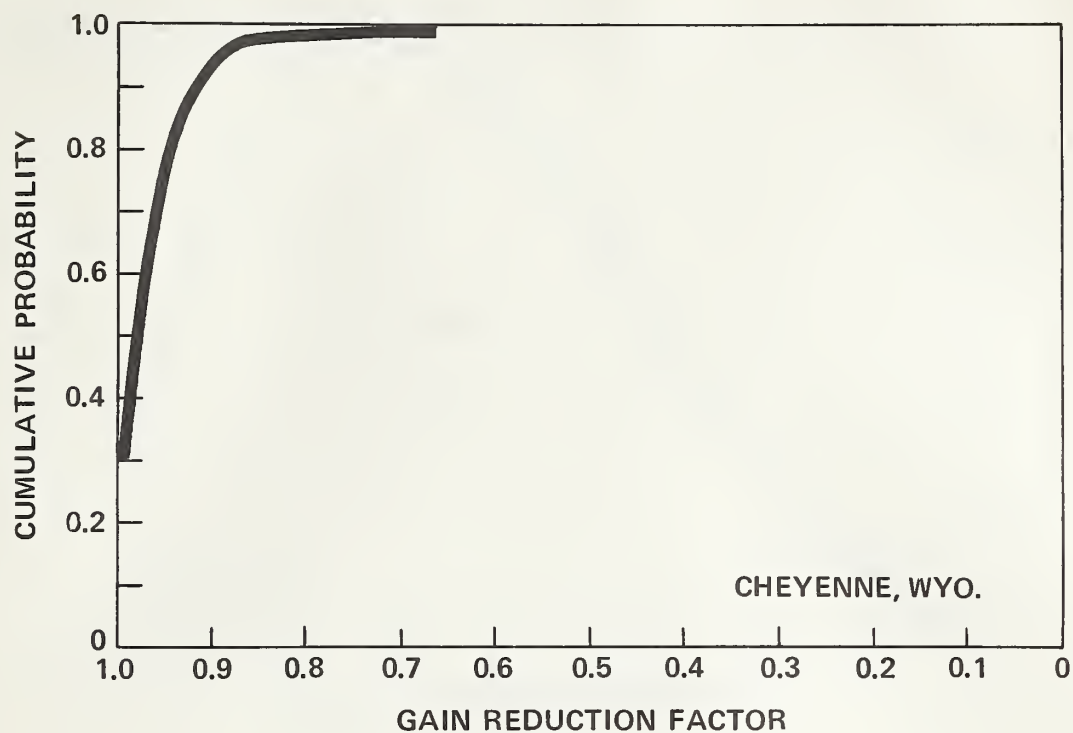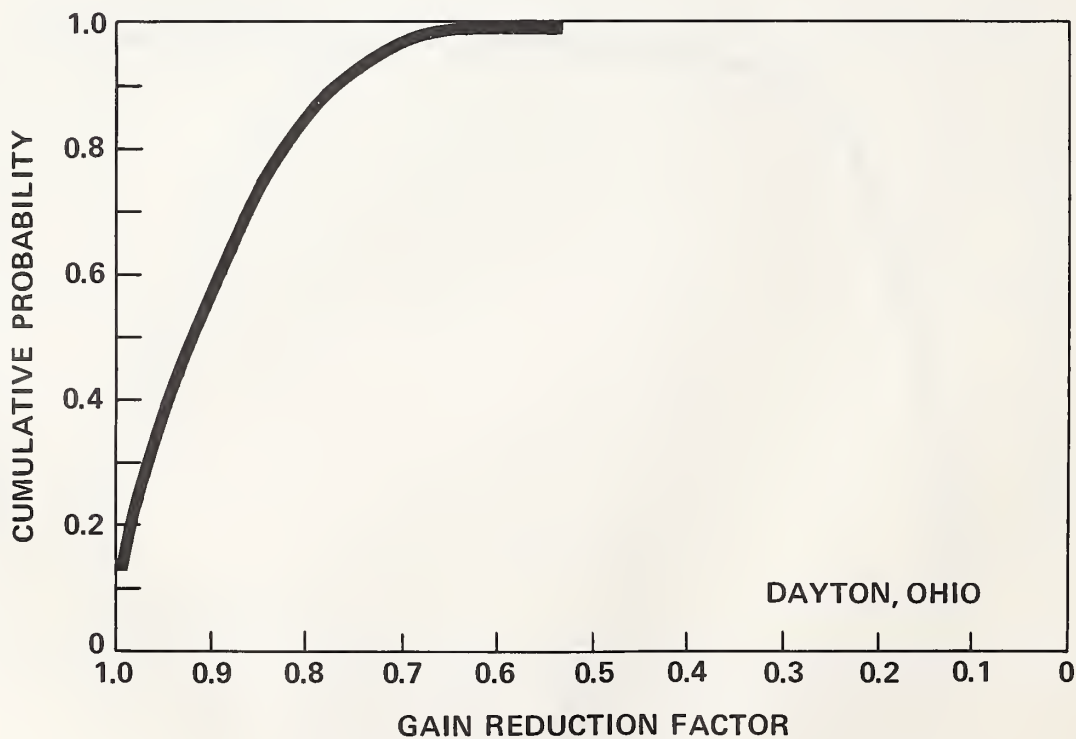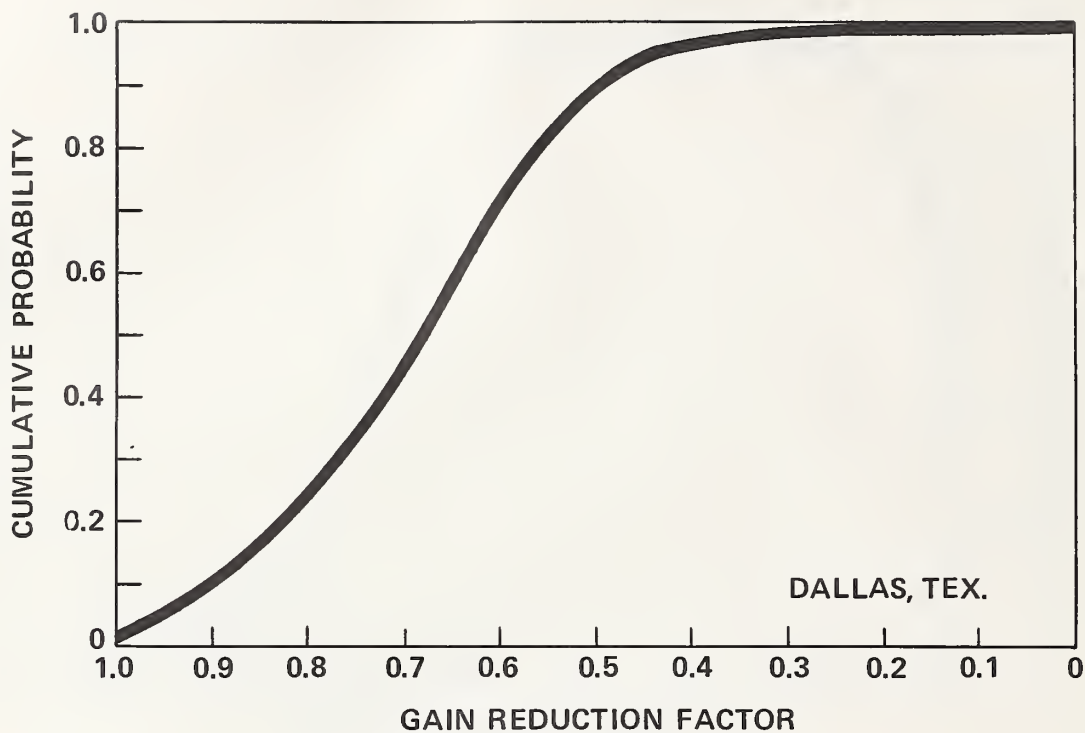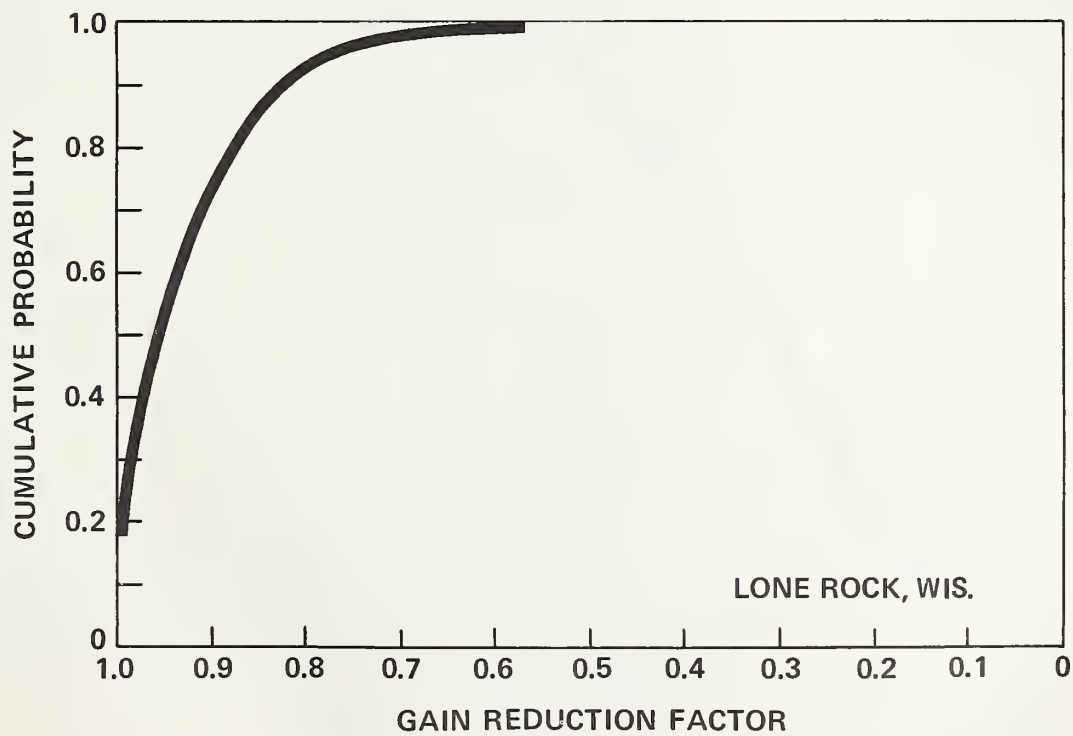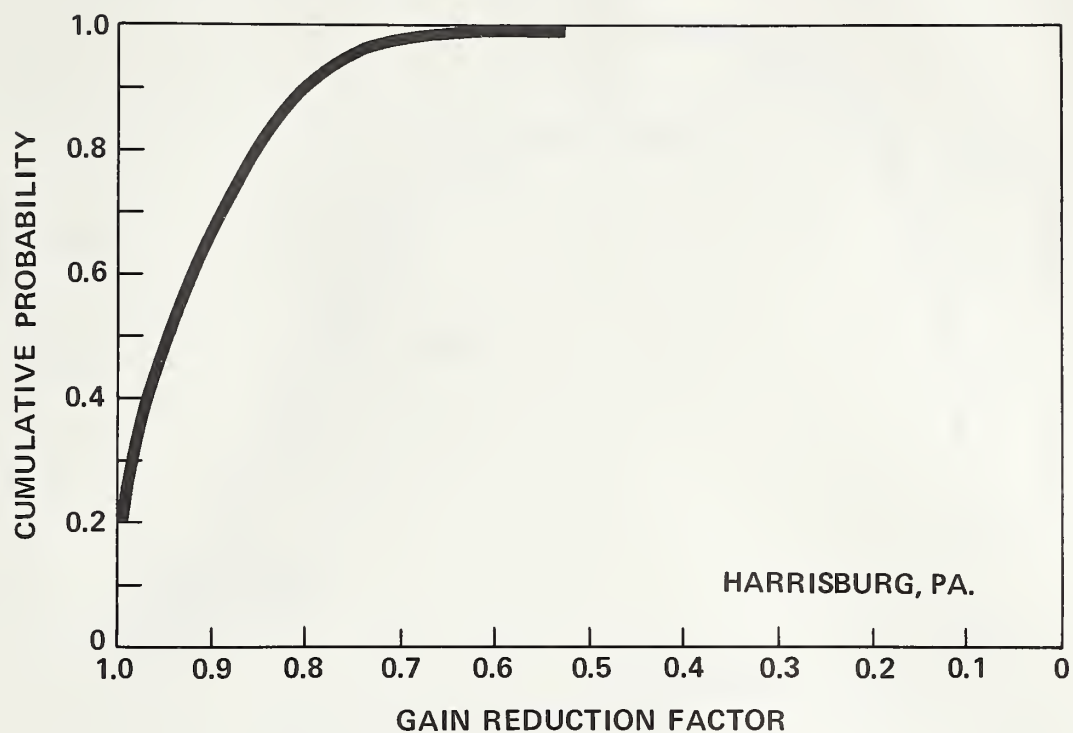Figure 5.--The cumulative probability (the probability the Gain Reduction Factor will be any specified value or larger) for 16 U.S. locations.

Figure 5.—Continued

Figure 5.—Continued

Figure 5.—Continued

Figure 5.—Continued

Figure 5.–Continued

OKLAHOMA CITY, OKLA.

GAIN REDUCTION FACTOR

PHOENIX, ARIZ.

GAIN REDUCTION FACTOR
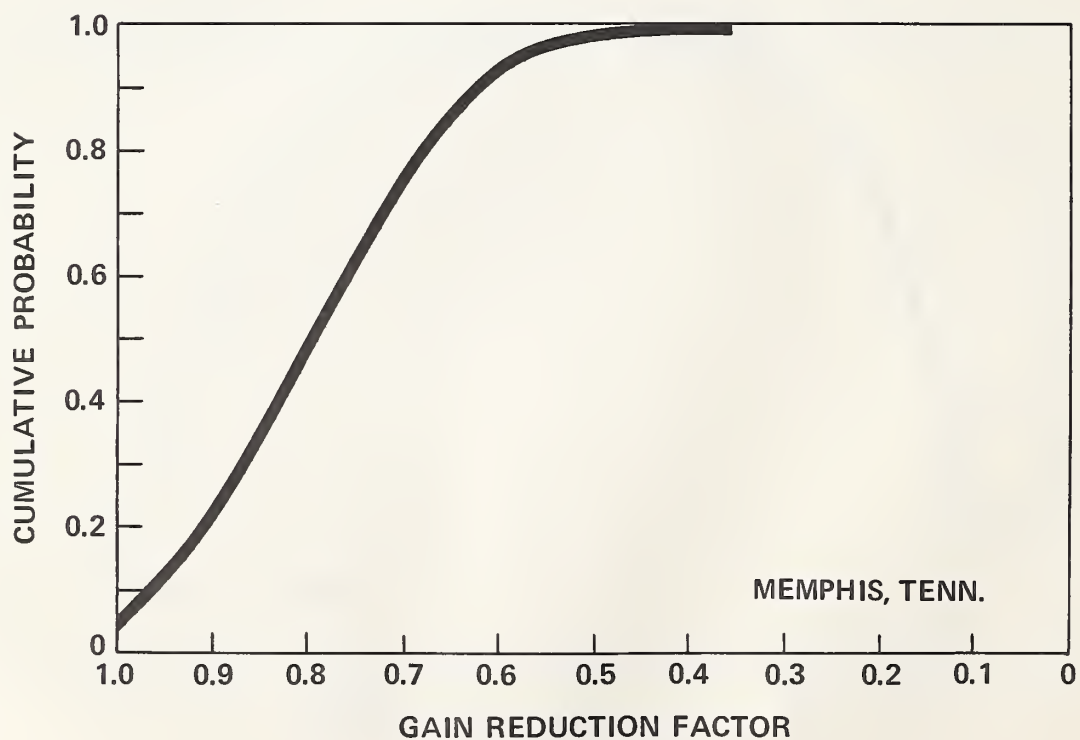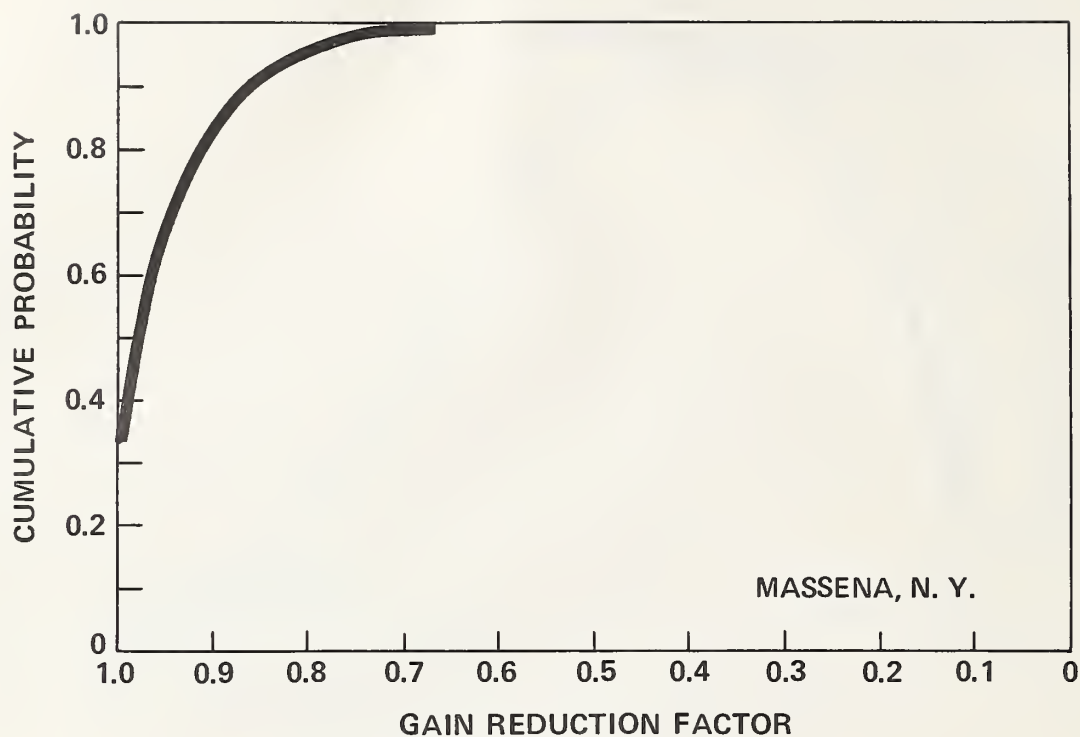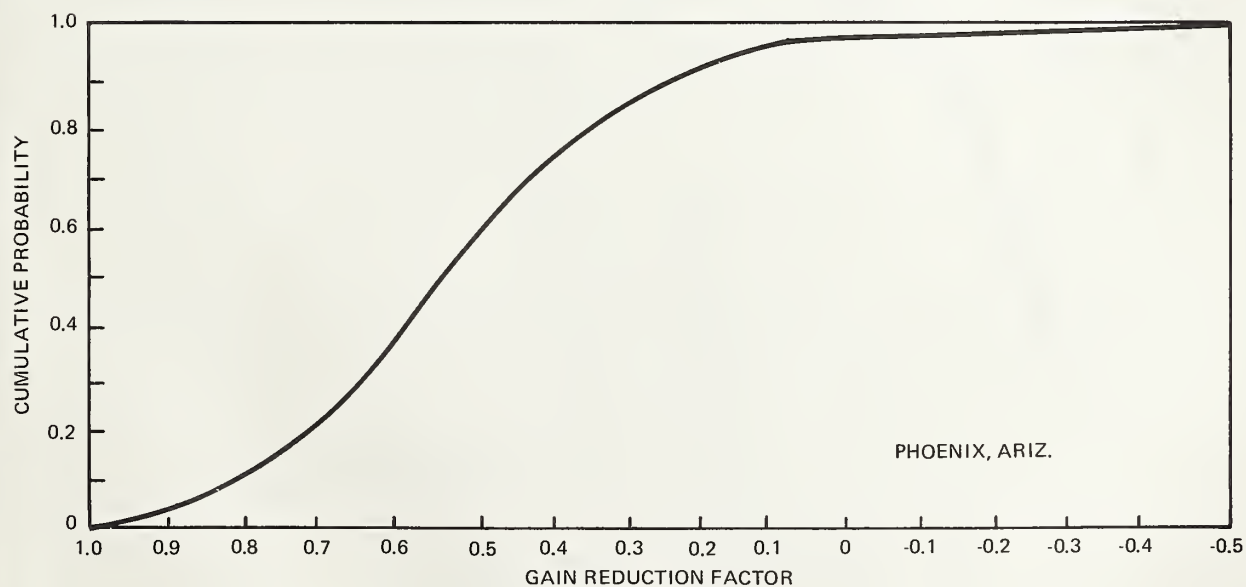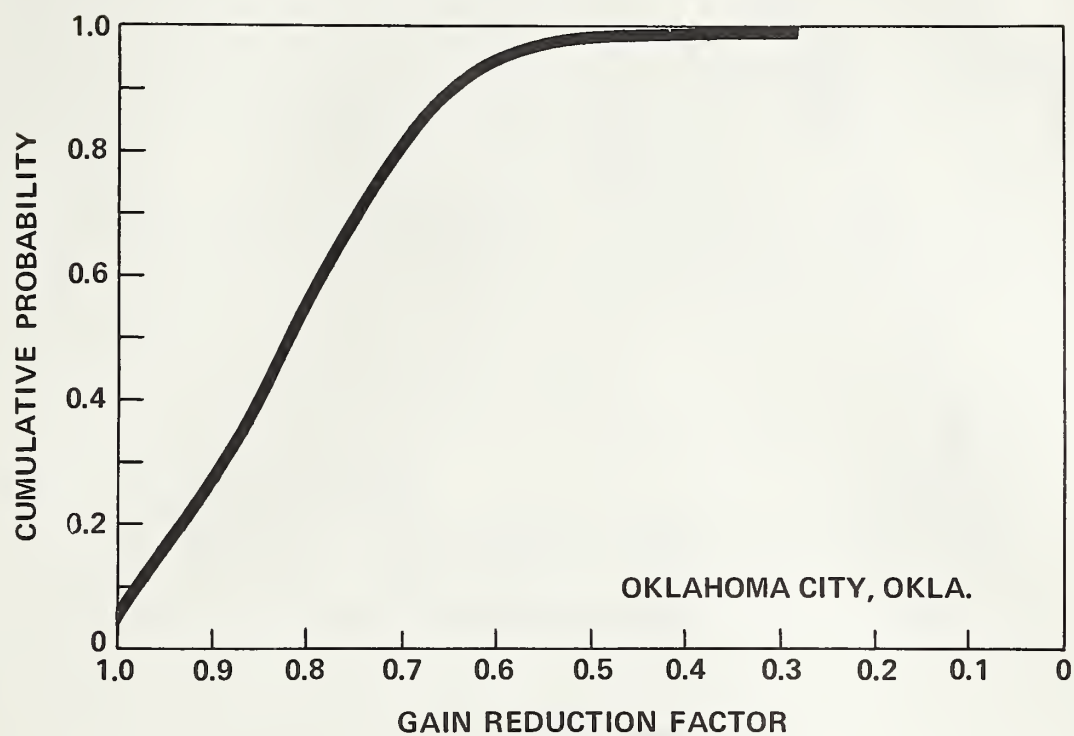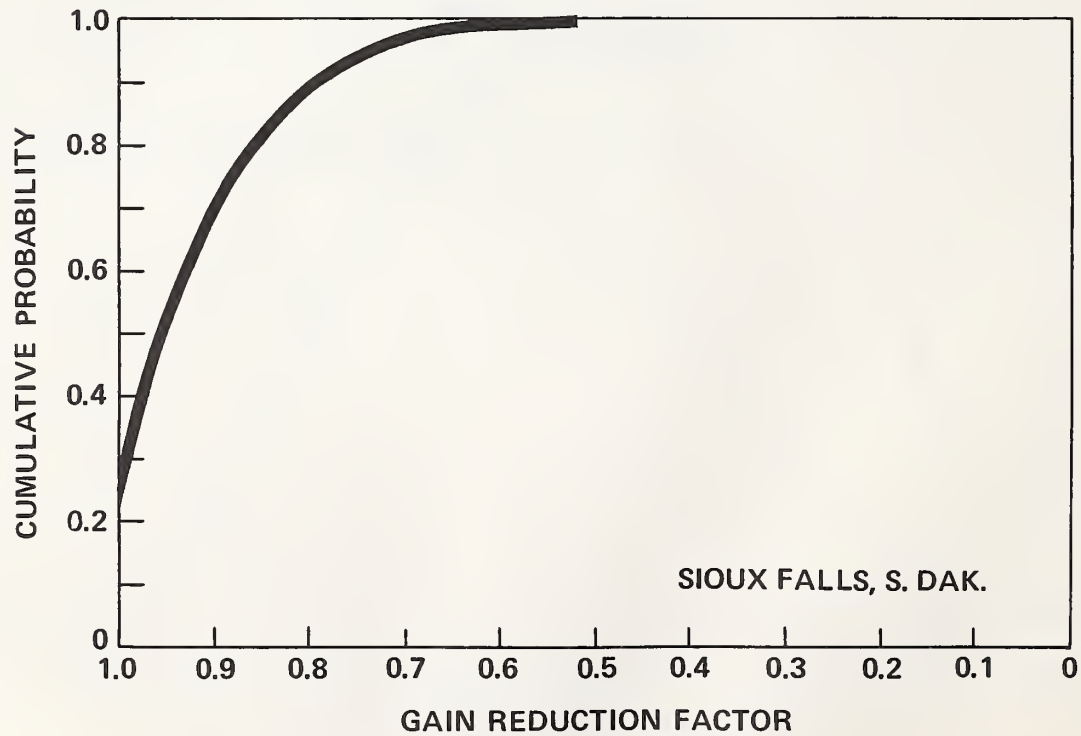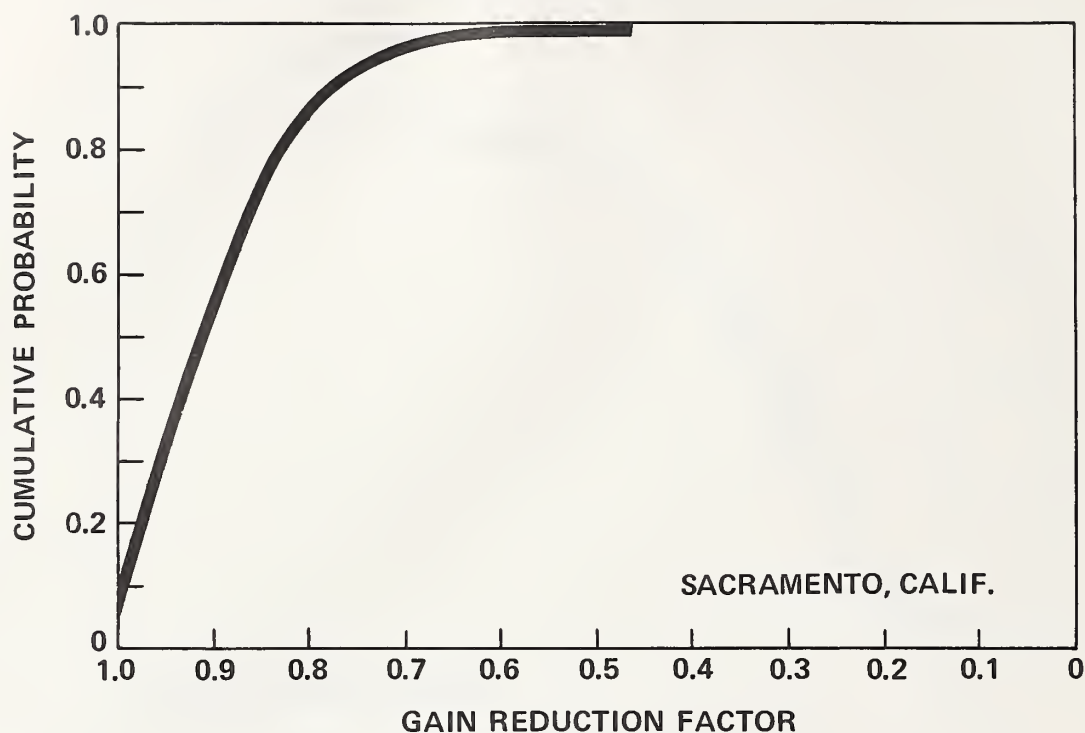
Figure 5.—Continued

Figure 5.—Continued

There may be a difference in the relative value of cumulative probability at two stations depending on the GRF chosen. For a GRF of 0.80 or *less*, Beeville, Tex., has a probability of 87 percent compared with 77 percent for Dallas, but at GRF = 0.60 or less, the probabilities are 9 and 30 percent, respectively. In other words, Beeville has more periods of mildly stressing conditions, but Dallas has more periods of severely stressing conditions.

The point at which the curve intercepts the y-axis indicates the probability that there would be no decline in production because of heat; for example, about 0.30 at Cheyenne.

which would be the seasonal production loss. A close approximation to integration is the weighted average:

$$\sum_{GRF=0}^{1.0} \frac{(GRF\ interval)\ (No.\ of\ days\ in\ interval)}{Total\ No.\ of\ days}$$

The resulting values for each station are shown in both table 1 and figure 6 as the mean GRF. These mean values are estimates of production loss for the entire
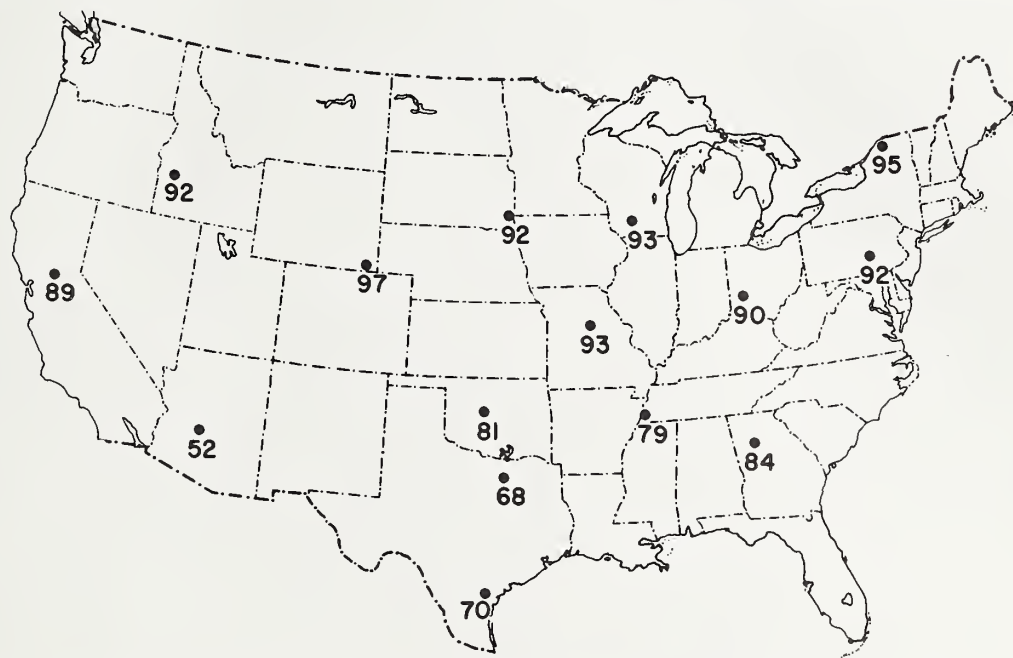


Figure 6.–Mean Gain Reduction Factors for the period June 1 to September 30 for certain locations in the United States.

When the curve for a station is used for another location, the climates of the two locations should be similar since local anomalies exist in most areas. The curve for Sacramento indicates a favorable situation–about equivalent to Sioux Falls, S.Dak. Yet, the frequent cool summer nights which are responsible for this do not occur much further north or south in the central valley of California, and the Sacramento curve would not be applicable to those areas.

Stations can be compared by various means. The cumulative probability for a specific GRF may be compared, and the values for GRF = 0.80 or greater for all stations are given in table 1. A more meaningful parameter would be an integration over a summer season

4-month period and would be generally applicable to spring-farrowed pigs. They could be used as a rational basis to determine whether a controlled environment for pigs would be profitable. For example, if a pig had a potential of gaining 2.00 pounds per day, under Oklahoma City conditions it would actually gain only 1.62 pounds per day, on the average, during the summer period. The value of this extra 0.38-pound/day pig could be compared with the costs of cooling to provide the necessary heat stress alleviation. If the finishing period included only part of the summer months, this should also be considered in the costs.

Use of these data is limited as the production relationship in this study was obtained under the

following conditions: Ad-lib feeding, same temperature of surroundings and air (no solar-radiation load), constant air temperature, light air movement, and lack of wallows or sprinklers. Findings from a previous study show that temperature varying diurnally about a mean resulted in a lower gain than that at the constant mean value, so production losses may be somewhat more than indicated here.[8] However, findings from another study (see reference listed in footnote 7) showed less production loss with increase in temperature than that used in the study here.

This analysis has been concerned with daily weight gain and not feed efficiency. In some situations, feed efficiency may be more important and generally is not adversely affected by moderately high temperatures (see footnotes 2 and 7).

[8] Bond, T. E., Kelly, C. F., and Heitman, H., Jr. Effect of diurnal temperature on heat loss and well-being of swine. Amer. Soc. Agr. Engin. Trans. 6: 132-135. 1963.